INTERACTIONS IN MULTIPLE AVOIDANCE SCHEDULES

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ABSTRACT

From a discussion of theories of behavioral contrast, it was concluded that earlier theoretical treatments of the topic, such as Reynolds' reinforcement frequency hypothesis, Terrace's response suppression hypothesis, and Bloomfield and Premack's preference theory of contrast were insufficent. A more recent theory, additivity (or response summation) theory was considered to put too much emphasis on pigeons as subjects. The first experiment therefore attempted to obtain behavioral contrast using another species, (rats) another response (two-way shuttle) and another type of reinforcement (negative). Behavioral contrast was not observed, but the obtained negative induction could be explained by an additivity theory.

An attempt was then made to determine under what conditions of relative shock density behavioral contrast would occur. Although day to day variations were high, obscuring long-term trends, neither behavioral contrast nor negative induction were suggested by the results, despite both increases and decreases in shock rate in the S2 component being used. The original studies showing multiple schedule interactions with negative reinforcement were then discussed, and it was concluded that a recent demonstration of contrast by de Villiers may well be a misinterpretation of the results obtained.

The significance of the findings for the field of behavioral contrast was discussed, with implications for future research pointed out.

1.1 INTRODUCTION

An experimental subject may be given access to a reinforcing event, such as food, according to any one of a number of schedules of reinforcement which are experienced successively. If each simple schedule is correlated with a different exteroceptive stimulus condition, the combined schedule thus produced is called a multiple schedule. For example, if, in the presence of a 1000Hz tone, a rat is reinforced on a variable-interval (VI) schedule, in which the interreinforcement interval varies about some mean value (e.g. 60 sec, hence VI60sec) and in the presence of white noise, reinforcement is scheduled for a fixed-interval (FI) of 60 sec (hence FI60sec), the combination of schedules is called a multiple variable-interval 60 second, fixed-interval 60 second schedule. This is customarily abbreviated to Mult VI60FI60. The simple schedules, (e.g. VI60) are referred to as the components of the multiple schedule.

In multiple schedules, response rate in one component is a joint function of the reinforcement conditions in that component, and the reinforcement conditions in the other component (or components). A change in one component may lead to response rate changes in the other, unchanged, component.

The paradigm experiment of the demonstration of such schedule interactions requires that initially a multiple schedule be set up in which stable baseline rates of responding may develop. Typically, a two-component multiple schedule is used which schedules equal rates of reinforcement in each component. An example would be MultVI60VI60.

Following this, the reinforcement scheduled on one component (called the S2) is withdrawn, so that the S2 becomes an extinction component and the multiple schedule a Mult VI60Ext. There are four possible changes that may occur to the response rates in the unchanged (S1) component. Reynolds, (1961a) classified these changes on the basis of the direction of change in response rate in the unchanged component, relative to changes in the response rate in changed (S2) component.

If the response rate in the S1 component increases, the interaction is positive; if the response rate decreases, the interaction is negative; if the change in rate in the S1 component is away from the rate in the changed S2 component, then it is termed contrast; if it is towards the S2 response rate the change is termed induction.

It is with the phenomena of positive behavioral contrast that this research is primarily concerned. This occurs when the response rate in the S1 component increases, away from the rate prevailing in the changed S2 component.

While Reynolds' definition of contrast has been widely accepted, (e.g. Catania, 1961; Terrace, 1963, 1968; Dunham, 1968; Weisman, 1969) it should be noted that there are many problems with this definition, and with other proposed definitions (Cf. Bloomfield, 1969; Premack, 1969).

A multiple schedule involving an extinction component as the S2 is not the only procedure which will give rise to positive behavioral contrast. Other schedules which give positive behavioral contrast when used as the S2 include: changes to lower rates of reinforcement (Terrace, 1968;

Thomas and Cameron, 1974; Weisman, 1969), differential reinforcement of low rates of responding (DRL) (Bloomfield, 1967; Terrace, 1968; Weisman, 1969), differential reinforcement of other behaviors, (DRO), (Reynolds and Catania, 1961), punishment for responding in the S2 component (Brethower and Reynolds, 1962; Terrace, 1968; Coates, 1972), reducing sucrose concentration of the reinforcer (Griffin and Cooper, 1971), delaying access to the reinforcer (Keller, 1970; Wilkie, 1971, 1972a; Richards, 1972), signalling reinforcement availability (Brownstein and Hughes, 1970; Brownstein and Newson, 1970; Baldock, 1970; Wilkie, 1973), and using concurrently reinforced treadle presses with reduced rates of reinforcement (McSweeney, 1975).

The last study pinpoints a number of problems with regards the definition of behavioral contrast. One, for example, is that behavioral contrast may not be the same thing for both concurrent and multiple schedules (McSweeney, 1975; Rachlin, 1973.) McSweeney's paper should be compared with those of Hemmes (1973) and Westbrook (1973), both of whom failed to find positive behavioral contrast using a treadle-press response.

All of the above studies have shown positive behavioral contrast using positive reinforcement; there appear to be only three studies showing multiple schedule interactions using negative reinforcement. Negative reinforcement occurs whenever the future probability of some response (e.g. bar-press) increases after that response has terminated or postponed some event (e.g. shock). The stimulus which is terminated by the response is called a negative reinforcer.

Wertheim (1965) showed positive behavioral contrast using free-operant avoidance, and de Villiers (1972), using 'random-interval' schedules of negative reinforcement also obtained contrast. Appel, (1960) using a free-operant procedure which approximates the behavioral contrast paradigm, found negative induction.

The phenomena is quite robust, especially with pigeons, but the theories proposed to explain it have not been. Most have toyed with either reinforcement or responding, or both, as being the only experimental parameters which could cause behavioral contrast. Until recently, none had succeeded. The research to be described is designed primarily to present fresh data which any proposed theory must account for, and so the theories of contrast are reviewed before the experiments are presented.

Since almost all the research concerns itself with positive behavioral contrast, I shall speak of "behavioral contrast", or simply "contrast" meaning always positive behavioral contrast. Similarly, all S1 schedules, unless otherwise stated, are VI schedules with various temporal parameters and are given first in the naming of a multiple schedule, e.g. Mult VI30(S1)VI60(S2). [1]

Within the realm of 'descriptive and theoretical rodentology', behavioral contrast and the associated

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[1] On a point of spelling, 'behavior' or 'behavioral' are used, not the more common 'behaviour' or 'behavioural'. As a glance at the references will show, we are stuck with American spelling.

phenomena of peak shift and inhibitory stimulus control are important processes which any general theory of learning (e.g. Herrnstein, 1970) or discrimination learning (e.g. Terrace, 1966b; Bloomfield, 1969; Halliday and Boakes, 1972) must attempt to give a close account of. Nor is it only important on theoretical grounds; as an additional factor in changing rates of responding, it has obvious relevance to behavior modification (cf. O'Brien, 1968; Nicholson and Gray, 1971). Yet despite this importance, theoretical accounts of contrast have tended to fare poorly - quite probably because they have been saying virtually the same thing.

Chronologically, the major accounts have been Reynolds' reinforcement reduction hypothesis, Terrace's response-reduction-S2 aversion theory, the preference account (Bloomfield, 1969) and more recently the additivity theory, also known as response summation (Rachlin, 1973; Keller, 1974; Schwartz, 1975).

Reynolds (1961a,b,c & d, 1963) suggested that one of the more important antecedents of contrast was a reduction in reinforcement in the S2 component. "The frequency of reinforcement in the presence of a given stimulus, relative to the frequency during all of the stimuli that successively control an organism's behavior in part determines the rate of responding that the given stimulus controls." (Reynolds, 1961a; p.70 italics his.) An increase in the relative frequency of reinforcement in S1 would mean an increase in the rate of responding, ie. contrast, in that component, when the reinforcement rate in the S2 component was reduced.

Supporting evidence appeared rapidly; Catania (1961)

showed that the magnitude of behavioral contrast increased monotonically with decreases in reinforcement in the S2 component, a finding confirmed by Reynolds (Reynolds, 1961b, p179.) Other data which supported Reynolds was Brethower and Reynolds (1962) who showed that where responding in the S2 component was punished, the behavioral contrast so obtained rose proportionately to the shock intensity. The shocks are to be seen as increasing the relative frequency of reinforcement in the S1 component. Wertheim (1965) showed that avoidance responding could be predicted on the basis of the relative rate of reinforcement, and obtained contrast. That he calculated rates as percentage of total shocks received, which is not supposed to be a good measure (de Villiers, 1972, 1974) we shall pass over in (comparative) silence. Bloomfield (1967a) and Nevin (1968) also showed experimental support for Reynolds.

However, despite their wide appeal, Reynolds' proposals would not cover the available data, as Reynolds himself had pointed out (Reynolds, 1963, 1968). Most of the studies cited in support of Reynolds had confounded suppression of responding and frequency of reinforcement in the S2 component. Changes in total frequency of reinforcement per session was another confounding factor. Reynolds and Limpo (1968) using a DRL schedule in S2, with signals for the previous IRT length found that in a Mult DRL DRL where signalling decreased pecks in the S2 component, an increase was found in the S1 component response rate, despite the fact that this reduced received reinforcement in the constant component. Even in 1961 Reynolds had said that

response suppression played an important part in the production of contrast. He now changed his approach and said that the initial research had failed to recognise the importance of changes in rate of responding.

Reynolds then turned to the other variable he had identified as important, namely response rate reduction. Most of the work in the area was done by Terrace. (Cf. Terrace, 1963, 1966a, 1966b, 1968, 1972.) Much of Terrace's view did not receive explicit formal statement prior to 1972 (Terrace, 1972), but inferentially can be gleaned from his earlier papers.

Terrace observed that when the S2 component began, pigeons would react 'emotionally' (rats, apparently, do not!). This was similar to the effects of frustrative non-reward, (Amsel, 1958). This "emotionality" during the S2 component, due to the response-suppression, created an aversive stimulus (the stimulus correlated with S2), the inhibition so developed being specific to the S2 stimulus. Concommitantly with the response suppression in S2 there is a non-specific effect which increases responding in the presence of all stimuli, including the S1, but excluding the S2. The excitatory effect was responsible for the increase in response rate in the presence of the S1 stimulus. What was essential for the production of contrast was response suppression in the S2 component.

Much of the data current at that time could be dealt with by such a proposal; for example, Brethower and Reynolds'

(1962) experiment may be reinterpreted by arguing that punishment in the S2 component suppressed responding, and hence gave rise to contrast, rather than a drop in the relative reinforcement frequency giving rise to contrast. In errorless discrimination learning, the S2 stimulus is faded in gradually, and the subject often never responds to that stimulus at all. No emotion is displayed to the S2, and no contrast is observed, since, according to Terrace, no emotion is elicited, and no response suppression can occur.

Disagreements with this view were numerous. Whether emotionality is a by-product, or a antecedent is never very clear; in fact, just what role the emotionality plays is quite obscure. Herrnstein (1969) has rather succinctly summed up on the role of second order constructs (emotions, etc.) in suggesting that it is better to leave the experimental parameters to explain the data than to propose dubious hypothetical entities (i.e., emotions and internal states) to do a job for which they were never designed, (Cf. also Hineline and Herrnstein, 1970). The definition of 'aversiveness', in relation to the S2 component and the response suppression stands in need of clarification. Such aversiveness is to be measured by an inhibitory gradient; the presence or absence of such a gradient is an empirical matter, requiring empirical support, since the two are usually defined separately, (Cf. Azrin and Holz, 1966, Hoffman, 1966.) This puts 'aversiveness' in the same position as an 'aversive stimulus' was in the Dinsmoor (1954) definition of punishment.

Theoretical considerations aside, Biederman (1967) showed an inhibitory gradient associated with an 'errorless' S2, a flat contradiction of Terrace's claims. Yet it is not immediately obvious whether the gradient should be peaked (Terrace, 1967) or flat (Deutsh, 1967). The problems that arose tended to arise more from the vagueness of Terrace's statements of his views than from any demonstratable error in reasoning. Although Terrace has recently extended his views to cover peak shift, and inhibitory stimulus control (Terrace, 1972), little work has been done following this line due especially to the emergence of additivity theory. What work has been done has repeatedly shown that contrast can occur without response rate reduction; a finding that additivity theory would predict (Cf. Baldock, 1970; Blampied, 1972; Wilkie, 1972b; Halliday and Boakes, 1971, 1974; Halliday and Boakes, 1974; Halliday, Boakes and Poli, 1975), and response pacing procedures. Bloomfield (1967, 1969) and also Premack (1969) attempted to state Reynolds' and Terrace's views in a nutshell by the assumption that, by whatever mechanism, a change in preference occurs between the components of a multiple schedule, giving rise to an increase in responsing in the S1 component. Implicit in this view is the assumption that a choice experiment would show an increased preference for the S1 component over the S2, after the introduction of the contrast-producing schedule in S2. Thus, contrast occurs whenever conditions in the S2 component 'get worse', in comparison to conditions in the S1 component.

While some have attempted to argue that an independent

measure of perceived value of reinforcement is not available, (for example, Baldock, 1970) there are in fact two similar procedures that will give such information; the concurrent chain procedure, which yields measures of schedule preference, and the experimental testing of the reinforcements presented, as suggested by Premack (1959) for their relative strengths. However, even if an independent measure of schedule preference is available, this still gives trouble, in much the same way that the Dinsmoor (1954) definition of punishment gave trouble. Before an experiment can be done exploring contrast, the schedules involved must first be checked to see that the S2 schedule is aversive. In principle, this should be done each time a schedule is used. It was said of the Dinsmoor definition, and can be said of the preference account of contrast, that a taxonomy of reinforcers can be derived. Such a suggestion must bear in mind the work of, for example, Redd, Sidman and Fletcher (1974) who showed that an event virtually always defined as a punishment, (time-out) functioned as reinforcing stimulus in their experiment.

Such a definition is conceptually weak, but one of its strengths is that it is amenable to some clear empirical testing. By signalling that the availability of reinforcement (Reynolds and Limpo, 1968; Baldock, 1970; Brownstein and Hughes, 1970; Blampied, 1972; Wilkie, 1973) obtained contrast, despite the findings of Lewis, Lewin, Stoyak and Muehleisen (1974) and Pliskoff and Green (1972) who have shown that signalled reinforcement is preferred to unsignalled reinforcement.

It is interesting to observe that while 'preference' may describe the relationship between components S1 and S2, having observed and described a change in preference between the two, the obvious question that would then arise is; what experimental parameter or parameters of the schedules give rise to the change in preference? Preference is not in itself a sufficient explanation of contrast.

Brown and Jenkins (1968) showed that a pigeon will peck a key that is illuminated a few seconds before food is presented. That such keypecking is robust was shown by Williams and Williams (1969) who demonstrated that such 'autoshaped' pecking continues even when pecking prevents food delivery. Tentative findings by Schwartz and Williams (1972) and Schwartz and Silberberg (1975) suggest that the 'autoshaped' keypecks can be distinguished from reinforcement-elicited keypecks by the duration of the peck. The bimodal distributions of response durations is not a clearcut categorization, however. Rachlin (1973) suggested that contrast may result from the interaction of the two different types of pecks. Rachlin's proposal was that "with a multiple schedule where response-dependent reinforcement is scheduled at different rates in component A and B the number of responses in a component would equal instrumental responses appropriate to the schedules of reinforcement in the component plus or minus responses from the excitatory or inhibitory effects of the stimuli signalling greater or lesser reinforcement". (Rachlin, 1973, p221.) Supportive evidence was plentiful. Redford and Perkins (1974) showed that contrast only occurred when the signal was

presented on the key, a finding confirmed by Schwartz (1975) and Schwartz, Hamilton and Silberberg (1975). Rachlin (1973) reports Gamzu, in a personal communication reporting that a 'nonlocalized' (i.e., auditory) stimulus associated with the S2 appeared to elicit pecks to the air, and the side of the cage. Hemmes (1973) found that keypecks gave contrast, but treadle pressing did not, i.e., there is response specificity about behavioral contrast. Probably the most significant evidence comes from Keller, (1974). Using 2 and 3 component multiple schedules, Keller found that when different keys were used to collect autoshaped and instrumental keypecks, in situations in which behavior contrast arose, the keypecks on the two keys added to an excess over baseline responding, but that instrumental keypecks actually declined, while autoshaped pecks increased, giving the number of pecks necessary for the behavioral contrast. Thus, the conditions that give rise to contrast can also give rise to induction, a very important finding, since as Rachlin, (loc.cit.) pointed out, when one abandons pigeons as experimental animals contrast becomes much less pervasive, and induction is much more commonly found. (Cf. Appel, 1960; Pear and Wilkie, 1971; Premack, 1969; Scull and Westbrook, 1973; Westbrook, 1973; Freeman, 1971.) There is a difficulty here, however, in that induction may be a function of a lack of stimulus control, as well as a schedule interaction.

While such a theory is attractive, linking a number of different areas as it does, and has received much support (Redford and Perkins, 1974; Keller, 1974; Gamzu and Schwartz 1973; Schwartz, 1975; Ricci, 1973, for example) it

appears to be unduly concerned with the behavior of pigeons. Yet many other animals have shown behavior contrast; turtles (Pert and Gonzales, 1974), rats (Guttman, Sutterer and Brush, 1975), humans (O'Brien, 1968; Nicholson and Gray, 1975), goldfish (reported by Pert and Gonzales, 1974).

There is nothing intrinsically wrong with a theory of contrast for pigeons only. It may well be that the mediation of contrast in pigeons is done by some process peculiar to pigeons, or peculiar to the keypeck; but any theory of contrast that also makes predictions about the behavior of other species is far more powerful than a non-inclusive theory.

In order to obtain comparative transitivity from an additivity theory, two things are needed. Firstly, the occurrence of autoshaping should be shown to be a more general phenomena; this has been partially carried out; in fish (Squier , 1969), rhesus monkeys (Sidman and Fletcher, 1968), bobwhite quail (Gardner, 1969), chicks (Wasserman, 1975), squirrel monkeys (Gamzu and Schwam, 1974), dogs (Smith and Smith, 1971), and rats (Peterson, Ackil, Frommer and Hearst, 1972; Stiers and Silberberg, 1974; Ponicki, 1974). Parenthetically, we should note in passing that Stiers and Silberberg made a noteworthy contribution in their demonstration of the cueing function of the lever, analogously to the key-light with pigeons. They did not, however, report anything like the wall-pecking which is reported to occur with pigeons. (Cf. Rachlin, 1973; Staddon and Simmelhag, 1971.)

The second requirement to show transitivity is that

differential responding should be shown in conditions giving rise to contrast, analogously to the demonstration by Keller (1974). Such experimental investigations as these should lead to evidence on which a response-summation or additivity theory of contrast may be either extended in scope to cover other species, or restricted to pigeons.

There is, however, one major problem for a response-summation or additivity theory of contrast. Using positive reinforcement, elicited pecks may give rise to contrast in pigeons; the effect appears to be response specific, as Hemmes (1973) shows. How does contrast occur in rats using a bar-press response, which is widely removed from the comsummatory response, unlike the key peck in pigeons? In situations such as that of Stiers and Silberberg (1974) the link can be made, but contrast can be shown in rats with nonlocalized stimuli used to signal the components. (Cf. de Villiers, 1972, used a buzzer; Beninger and Kendall, 1975, used a houselight.) Even if an additivity theory of contrast could deal with this, assuming as it does the autoshaping of lever-pressing with rats, (without cue lights) such a theory would then have to try to cope with the data from studies employing negative reinforcement. (Wertheim, 1965; de Villiers, 1972) Data such as this forces us to assume that a stimulus which is correlated (either positively or negatively, it is not clear which) with shock or some other aversive stimulus can elicit bar-pressing. Rachlin (1969) has made a tentative demonstration of such a phenomena in pigeons, but its occurrence in rats has yet to be shown. The presence of such stimuli in the setting may

be open to a number of possible interpretations, such as Weisman and Litner's suggestion that a signal for shock-free periods may act as a conditioned positive reinforcer. (Weisman and Litner, 1969) Thus, demonstrations of behavioral contrast using negative reinforcement, with rats, could cast some doubts on the usefulness of additivity theory as an explanatory device.

The data that is available concerning contrast on negative reinforcement is, however, highly equivocal. Appel, (1960) found negative induction as the general interaction effect. Wertheim (1965) showed positive contrast, but there are some methodological anomalities about this study which make it somewhat unsuitable for analysis of contrast effects. De Villiers (1972) then becomes one of few studies which show a direct analysis of contrast in multiple avoidance schedules.

The response modality employed by de Villiers was a bar-press. The response modality has already been shown to be important in contrast (Hemmes, 1973) and, since virtually all studies of contrast in the rat have employed the bar-press, often with signal lights close to the bar (e.g. Wertheim, 1965) a demonstration of contrast using another response modality, and with a nonlocalized signal, would be a strong link in a chain of evidence that an additivity theory would have much trouble in explaining. On the other hand, a finding of negative induction in such a setting could be taken to support Keller (1974).

To employ a different response, using negative reinforcement, is not too difficult. Head pokes, one-way

avoidance, two-way shuttle, treadle presses, wheel running, etc., could all be employed. But most negative schedules employ the usual free-operant avoidance task, with a fixed response-shock (R-S) interval, and a fixed shock-shock (S-S) interval, which give rise to temporal regularities which are not usually present in most of the contrast studies. To avoid this, one may use de Villiers' random interval (as he termed it) or variable interval avoidance, which has none of the fixed temporal patterns of the free operant avoidance. Reiss and Farrar, (1972) have shown the two-way free-operant shuttle response to be easy to learn, and very stable over long periods, an ideal baseline for interaction studies. Additionally, it does not involve any major deviation from de Villiers' procedure. By combining these two procedures, it is possible to see if contrast will result from a changed response modality.

2.1 EXPERIMENT ONE

2.1.1 Method

The subjects were four naive female hooded rats, approximately 120 days old at the beginning of the experiment. They were housed in a group cage (30.5 x 38 x 46 cm) and recevied free access to food and water. The deviation from the usual practice of housing subjects individually was prompted by suggestions that individually caged animals exhibit behavioral and physiological anomalities. (Cf. Wettman, et al., 1968; Hatch, et al., 1963; Syme, 1972.)

2.1.2 Apparatus

The experimental chamber consisted of two Lafayette Modular Testing Units, (Model A550) connected by a door which, when open, permitted access to both units. The action of the door was controlled by the session timer. It was opened to begin, and closed to end the session, thus preventing responding outside the experimental session. The units were lit by white light through the translucent roof, and the two units were enclosed in a wooden enclosure to provide some degree of sensory isolation.

The floor of each unit consisted of 18 bars, 0.5cm in diameter, spaced 1.7cm centre to centre. These bars formed a tilting platform, which was balanced from outside the box.

Depression of the floor bars by a weight exceeding 180 gm closed a microswitch. Associated logic circuitry ensured that only alternating switch closure registered as responses, where a response was defined as a

movement from one side to the other. The settings of the equipment were checked daily for false positive or false negative responses. The two units were separated by a gap of 2-3mm, and were not mechanically linked. Each unit was mounted on a thick sheet of foam plastic. These precations minimised the possibility of vibration-induced false positives. A response was signalled to the animal by switching the house light off for 100m sec.

Shocks were delivered through the floorbars only. The shock was an alternating current delivered by a BRS Foringer shock generator, (Model SG901) which was passed through a BRS Foringer shock scrambler (Model SC901), altering the polarity of the individual bars 100 times per second.

White noise from a Grason-Stradler generator (Model 901B), set at 72db (range 96-75db) and band width 0-20,000 cps was used and a 1000 cps tone was used as a discriminative stimulus.

Programming of experimental events was carried out using a combination of electromechanical and solid state equipment. Scheduled shocks, received shocks and responses were recorded on counters, and additional information was recorded on a Gerbrands cumulative recorder.

2.1.3 Procedure

The experimental paradigm and shock scheduling follow de Villiers, 1972 (Exp 1), while the response was the two-way shuttle response (instead of a bar-press) used by Reiss and Farrar (1972).

In all phases, the shock parameters were constant, 1.5mA, duration 0.3sec. If the animal crossed from one

unit to the other, as described, this cancelled the next scheduled shock, but did not affect any other programmed shock, independently of whether or not the previous programmed shock had been delivered. Any response after the initial shock-cancelling response had no effect on the future probability of shock. The order of running animals was routinely changed each day, as was the side of initial entry. After preliminary training, all sessions were two hours in duration with a warmup period of 15 minutes. (Reiss and Farrar (1972) noted that the warmup was about 7 minutes.)

Phase 1: Habituation and Training

On the first day subjects received a 2 hour period of habituation in the box with both sides accessible, and no shocks were delivered. On the following six days they received daily 1½ hour sessions of free-operant avoidance. (S-Sinterval = 6sec., R-Sinterval = 6-12 secs.)

Phase 2: VI 15 Avoidance Training

The assignment of intershock intervals was carried out using the Fleshler and Hoffman (1962) procedure for variable intervals, and randomly assigning the obtained inter-shock periods. This assures a rectangular distribution of shocks. There were ten sessions in this phase.

Phase 3: Multiple VI 15 VI 15 Avoidance Training

The single VI schedule was changed to a multiple schedule by signalling one component, using the 1000 cps tone, counterbalanced between subjects. There were 15 recorded days in this phase, although four days were lost

due to moisture on the grid bars reducing the shock intensity to very low levels.

Phase 4: Multiple VI 15 VI 60 Avoidance

One component of the original Mult VI 15 VI 15 schedule was changed to a VI 60 schedule, thus making a Mult VI 15 VI 60 schedule. Tone was again counterbalanced. There were 15 experimental sessions in this, the experimental phase.

Phase 5: Multiple VI 15 VI 15 Avoidance

Phase 5 represents a return to the original baseline conditions, with the VI 60 schedule changed for the VI 15 schedule.

3.1 RESULTS AND DISCUSSION

3.1.1 Results

Phase 1 and 2: Habituation and Single VI15 Training

All subjects learnt the response readily, but, contrary to the findings of Reiss and Farrar (1972) acquisition data suggested that overall performance, in terms of shock frequency reduction was poor. Using a R-S interval of 20sec., and a S-S interval of 5 sec., rats were able to reduce the received shock from a maximum of 12 shocks per minute, to an average of .15 to .2 shocks per minute after 6 sessions. In the present experiment, with 4 shocks scheduled per minute, no subject reduced received shocks to below 1 shock per minute, and using free-operant avoidance, the average received shock was 2 shocks per minute, using a R-S interval of 12 seconds, and a S-S interval of 6 seconds. There were no failures to learn.

Phase 3: Mult VI15VI15

Four days were lost in this phase (see dotted vertical line, Figures 1, 2, 3 and 4) due to moisture in the floor bars reducing received shock intensity by approximately half. The dominant trend in this phase is a consistent and clear long-term decrement in performance, as shown by the decline in rates of responding, and the decline in shock frequency reduction. The failure to obtain stable baseline rates of responding makes any comparisons between this, and the Mult VI15VI60 phase difficult. The presence of the tone, which was on different components for different animals, had no effect on rates of responding.

Phase 4: Mult VI15VI160

For subjects F1, F2 and F3, the introduction of this phase led to an immediate reduction in the rate of responding in the S2 component (shown by the triangles in Figures 1-4) and a reduction also in the rate of responding in the S1 component. This effect is negative induction. For F4 there is a small decrease, but it may equally as well represent the continuation of the on-going long-term decrement in response rates. Whether or not this observed downward trend may be judged to be negative induction depends primarily on the outcome of the following phase.

Phase 5: Mult VI15VI15

In all cases except F2 the response rates in the S1 component increased, against a trend of long-term decreases. The effect is small, and does not show up very much at all in the shock frequency reduction graphs (see Figures 3, 4).

In all subjects, there was some evidence for negative induction, either from reduced responding in the experimental period (Phase 4), or else in the positive induction that occurred on the reintroduction of the Mult VI15VI15 schedule. This effect was obscured by the presence of long-term decrements in response rates. That there was no lack of stimulus control is clear from the rates of responding in the two components. That such a decrease in response rate should occur is somewhat surprising, since most of the animals were already receiving between 40 and 50 percent of all scheduled shocks at the end of the first Mult VI15VI15 phase. (Cf. Figures 3 and 4.) The shock frequency reduction data for the VI60 sec. component

has been multiplied by four to make it proportional to the S1 component data. Interestingly, although the scheduled shock rate has dropped fourfold, the shock frequency reduction remains proportionally the same, despite the fact that on a VI60 schedule the animal has a much better chance of avoiding shocks, especially the most frequently received, namely the shorter S-S intervals, such as 3 sec. This suggests that the majority of responses are being emitted immediately after a shock has been delivered, rather than at some post-shock interval. Anecdotally, this was observed to occur, but firm data is lacking.

3.1.2 Discussion

Reiss and Farrar (1972) found that rats trained in a two-way shuttle avoidance exhibited very fast acquisition, with no shaping required, no failures to learn, a minimum of 'bursting', and a higher percentage of shocks avoided than is customary in traditional types of avoidance, and no long term decrements. In the present setting, with a response which most writers (Bolles, 1972; Seligman and Hager, 1972) would classify as either a 'prepared' response or a 'species specific defence reaction', acquisition was no faster than that found later with bar-pressing as a response. We have already commented on the very poor avoidance found, and the long term decrements are evident in the graphs. If bursting is defined as responding immediately after a shock (Sidman, 1958), most of the responding in this experiment would probably have come under such a heading. Evidently we must conclude that rats are 'prepared' to learn a free-operant two-way shuttle avoidance, but not a variable interval two-way

shuttle avoidance; but 'preparedness' and 'species specific defence reactions' were not supposed to be schedule-bound.

Whether or not the observed disparity between the Reiss and Farrar findings and the present findings are attributable only to the change in schedule we are unable to say, there being no data available which would give a satisfactory answer.

If we take either a reduction in response rate after the introduction of the Mult VI15VI60 or an increase after the reintroduction of the Mult VI15VI15 as criteria, then allowing for the obscuring long-term decrements, a modest interaction - negative induction - was found. This finding was further obscured by the very low prevailing response rate. A behavioral contrast effect would have been readily apparent, but it is doubtful if the rats in this study could have reduced their rates of responding very much at all; that they did reduce at all was surprising.

If Keller's findings (Keller, 1974) with pigeons are valid for rats, then the presence of a negative induction interaction suggests that, while some of the relevant conditions for behavior contrast were present, (giving rise to a small decline in reinforcment-directed responses), there were no stimulus-reinforcer interactions which gave rise to elicited (or autoshaped) responses. Thus we may say that autoshaping would not have occurred in this experiment with these animals. At the present time, there has only been one study which attempted to autoshape using negative reinforcement, Rachlin (1969), using pigeons, showed that autoshaping, and presumably stimulus-reinforcer relationships, may occur in the pigeon using negative reinforcement,

in his case shock. That was the only report, and it has not been shown for rats.

One other issue still remains ambiguous. If we assume a preference theory of contrast, it seems reasonable to suggest that a lower frequency of shock is preferred to a higher frequency. (Cf. Lambert, Bersh, Hineline and Smith, 1973.) Consequently, for conditions to get worse in the S2 component, the shock rate should be increased, as from VI30 to VI15. Contrast should then result. De Villiers (1972, exp 2) found a temporary positive behavioral contrast effect, for 3-7 sessions, followed by a pronounced negative contrast effect. When conditions improved in the S2 component, a contrast effect was observed, although we shall argue later that such an effect is highly debatable. Wertheim (1965) also found contrast when he reduced the number of scheduled shocks in the S2 component, but he was manipulating the R-S and the S-S intervals at the same time.

The next experiment is a systematic replication of the de Villiers (1972) experiment, to attempt to determine the effects of increases and decreases in the scheduled shock rates, using the VI avoidance schedule. The prescence of positive behavioral contrast would give an experimental situation which could be later explored to see if such a situation gave rise to autoshaped responses.

4.1 EXPERIMENT TWO

4.1.1 Method

The subjects were 6 naive female hooded rats, approximately 120 days old at the beginning of the experiment. They were reared and housed in the same environment as the subjects of the first experiment.

4.1.2 Apparatus

There were two identical experimental chambers, housed separately in a chest, which attenuated light and sound. The chambers were both La Fayette Modular Testing Units (Model A550), fitted with a BRS retractable bar, model 901/292-10. There were 18 floor bars in each unit each 0.5cm in diameter, placed 1.7cm centre to centre. All shocks were delivered through the floor bars only. There were two shock sources, one for each box. Both delivered alternating current scrambled shocks. Shock unit 1 was a BRS Foringer shock generator (Model SG901) and a BRS Foringer shock scrambler (Model SC901), which altered the polarity of the individual bars 100 times per minute. The second shock source was a Grason Stadler shock generator and scrambler (Model E6070B).

White noise was delivered by the same system used in the first study. The programming of experimental events was carried out using a system of electro-mechanical relays which determined whether or not a programmed shock should be delivered or not, for each box individually. Thus a single VI programme was used to schedule shocks for the two subjects, run simultaneously. Scheduled shocks, received

shocks, and responses were recorded on counters, and additional information was recorded on a Gerbrands cumulative recorder.

4.1.3 Procedure

This experiment employed a bar-press response, and used a basic VI30 sec. avoidance schedule. Three animals were changed from a Mult VI30VI30 to a Mult VI30VI60 schedule and the other three animals were changed from a Mult VI30VI30 to a Mult VI30VI15 schedule.

In all phases of the experiment, the shock duration was 0.3 sec., and the shock intensity was 1.6mA. (The Grason Stadler system did not allow the use of 1.5mA) A single response was sufficient to cancel the next scheduled shock, but had no other effect on the future probability of shock, independently of whether or not the previous shock had been delivered. The box in which an animal was run was routinely changed on a random basis, and all sessions were of 1½ hours duration, data being recorded only from the last hour.

Phase 1: Habituation and Training

On the first day, all animals were given experience of the experimental boxes for 1½ hours. All equipment was running, but no shocks were delivered. The next three days the rats were trained to bar-press, then run on a free-operant avoidance schedule as described in the previous experiment (S-S = 6sec., R-S = 12sec.)

Phase 2: Avoidance Training, Single VI30

After the three days on the free-operant schedule,

EXP. 2

FIG. 1

SUBJECT: R1

GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

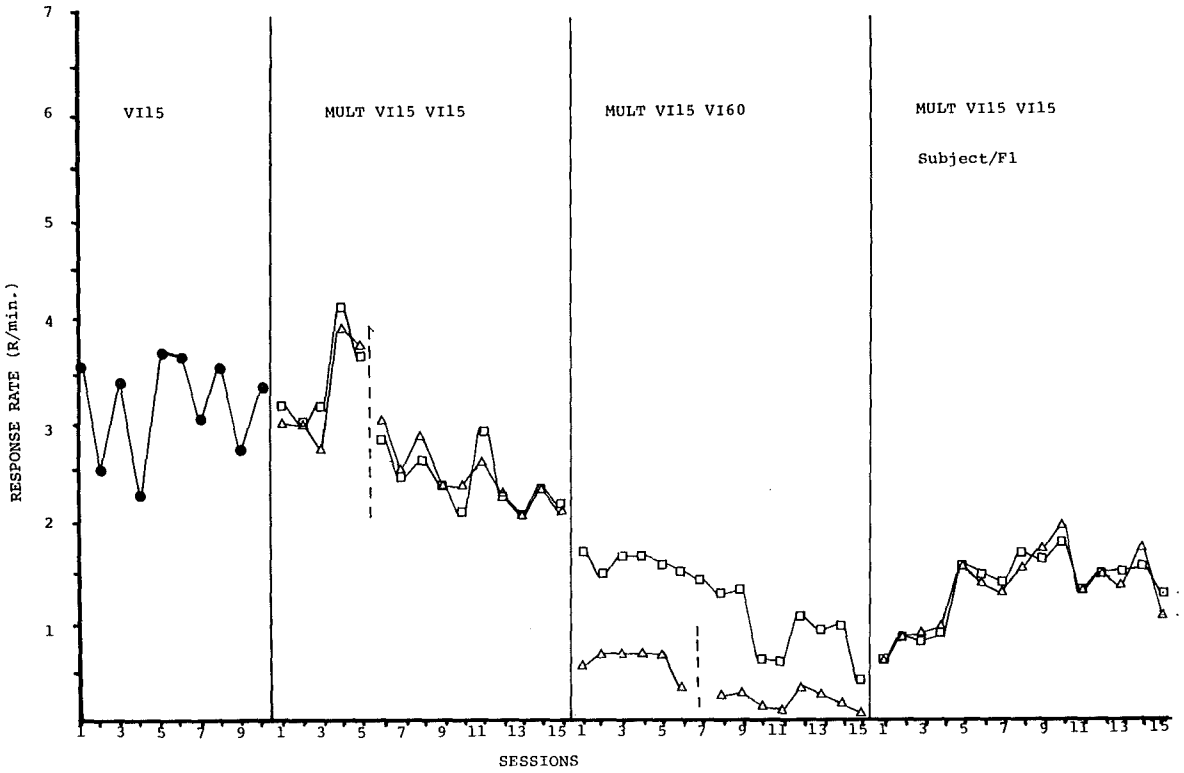
The calculation of relative response, and received shock rates, using the formula A/A + B, uses the data from the S1 component as A; S2 data for B.

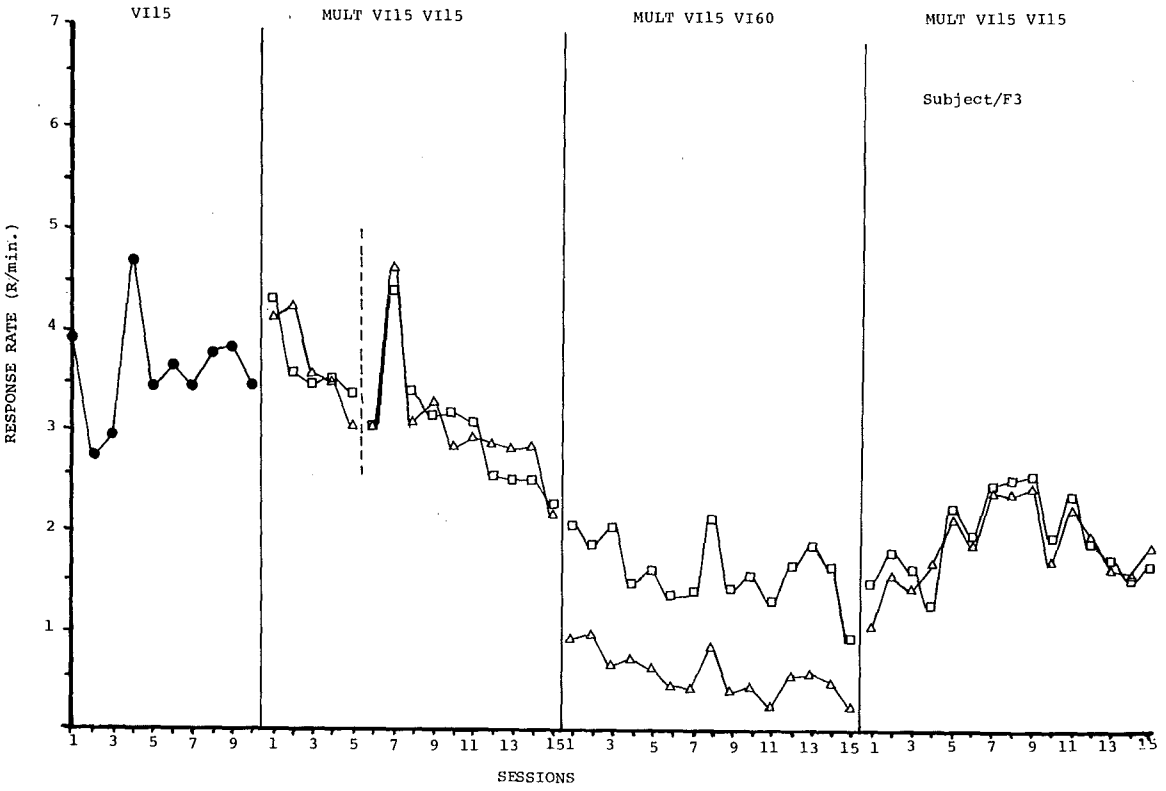
EXP. 1

FIG. 1

SUBJECTS: F1 & F3

GRAPH OF AVERAGE RESPONSE RATE PER SESSION. S1 COMPONENT MARKED BY SQUARES, S2 COMPONENT MARKED BY TRIANGLES.


VI15
MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F1
RESPONSE RATE (R/min.)
SESSIONS

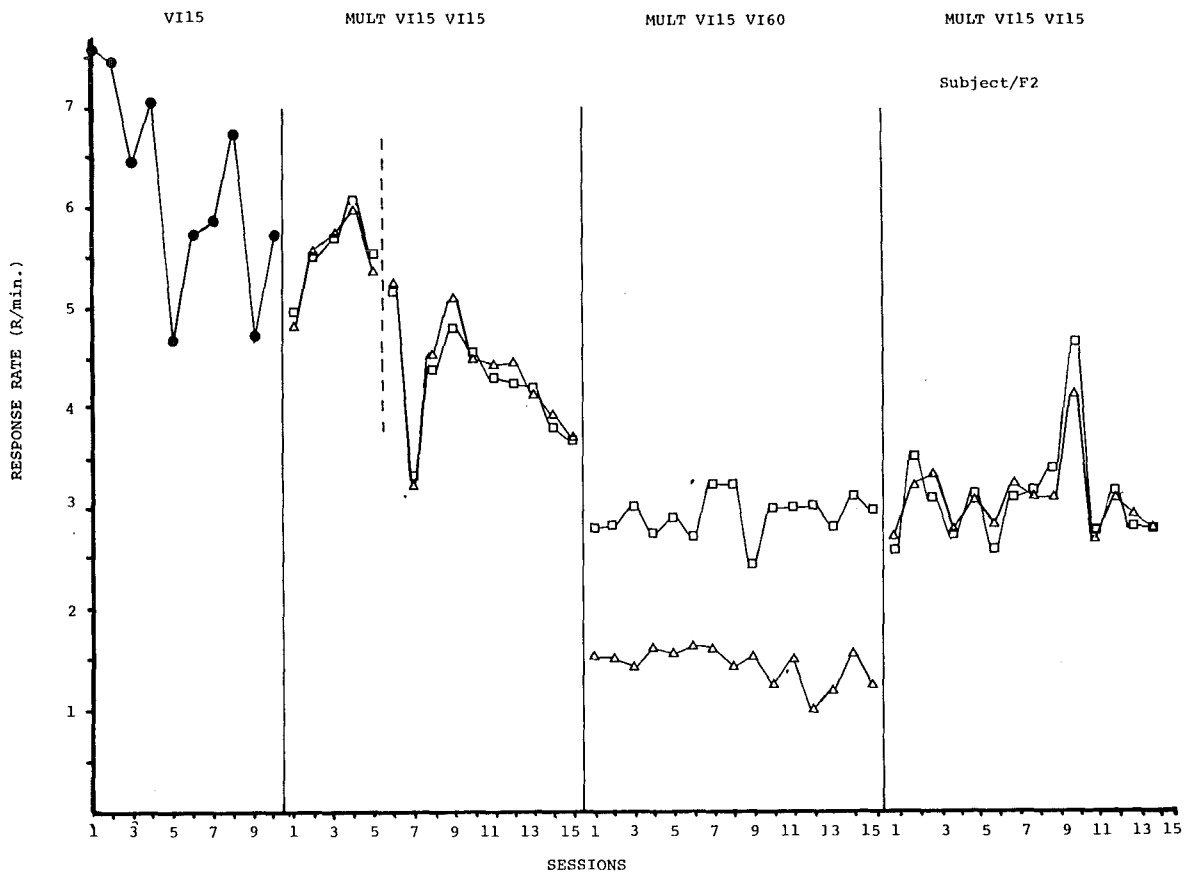

VI15
MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F3
RESPONSE RATE (R/min.)
SESSIONS

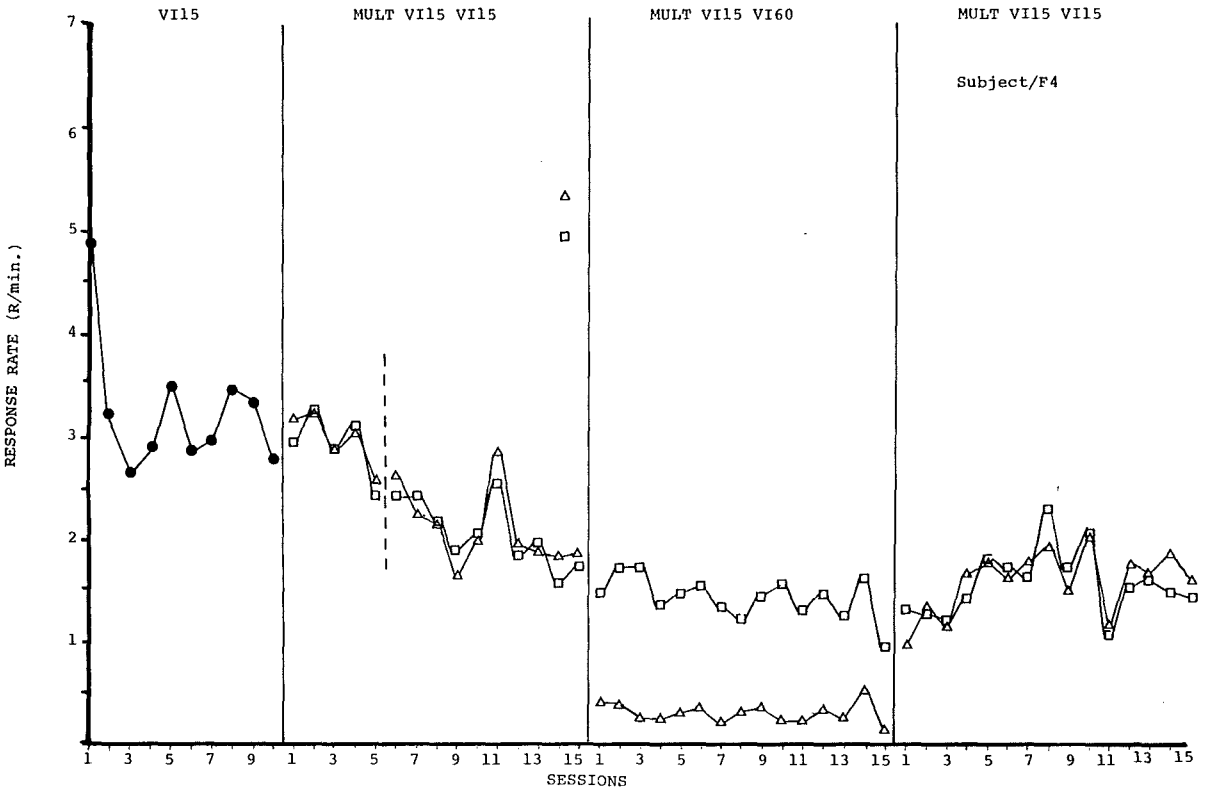
EXP. 1

FIG. 2

SUBJECTS: F2 & F4

GRAPH OF AVERAGE RESPONSE RATE PER SESSION. S1 COMPONENT MARKED BY SQUARES, S2 COMPONENT MARKED BY TRIANGLES.


VI15
MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F2
RESPONSE RATE (R/min.)
SESSIONS


VI15
MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F4
RESPONSE RATE (R/min.)
SESSIONS

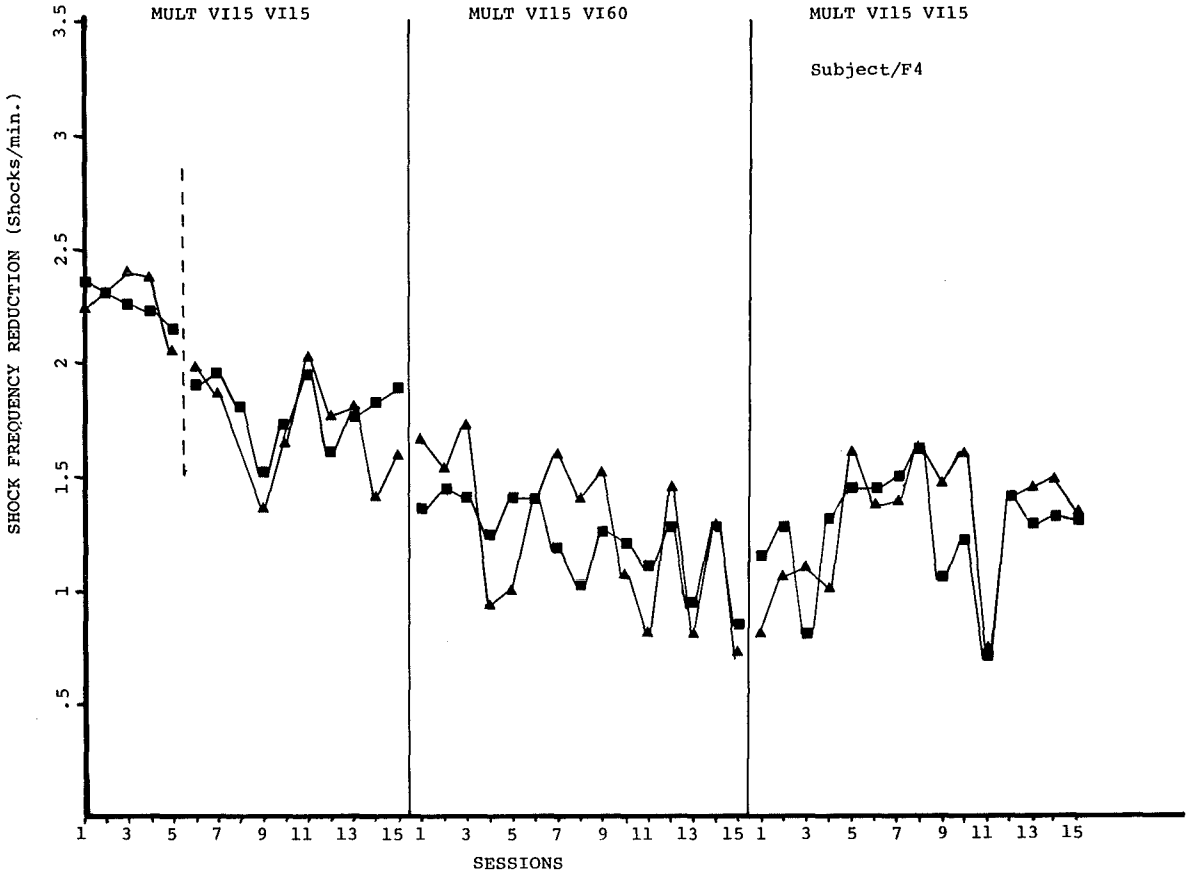
EXP. 1

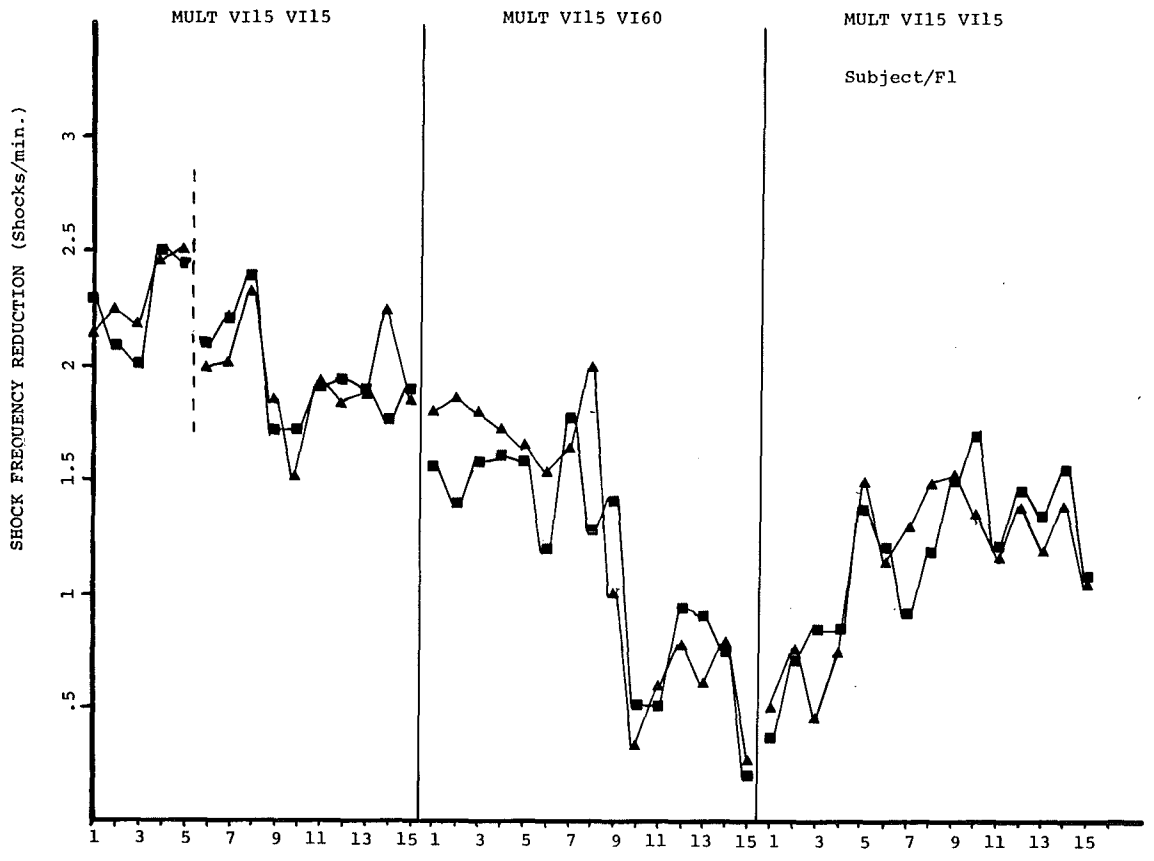
FIG. 3

SUBJECT: R1 & F4

SHOCK FREQUENCY REDUCTION, AVERAGED PER SESSIONS.

S1 COMPONENT MARKED BY SQUARES, S2 COMPONENT MARKED BY TRIANGLES.


MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F4
SHOCK FREQUENCY REDUCTION (Shocks/min.)
SESSIONS


MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F1
SHOCK FREQUENCY REDUCTION (Shocks/min.)

EXP. 1

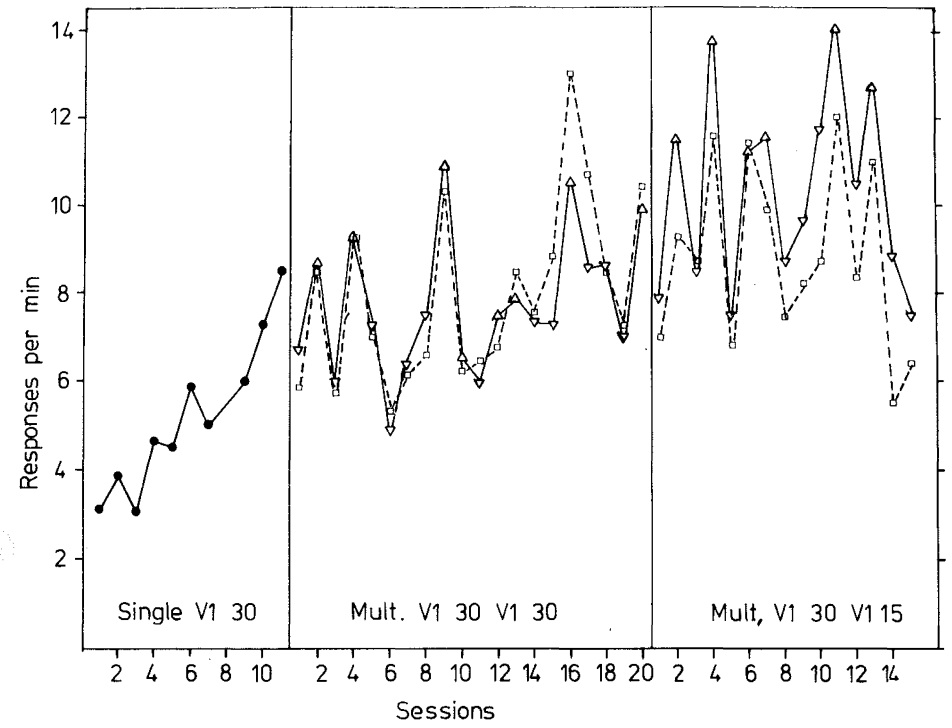
FIG. 4

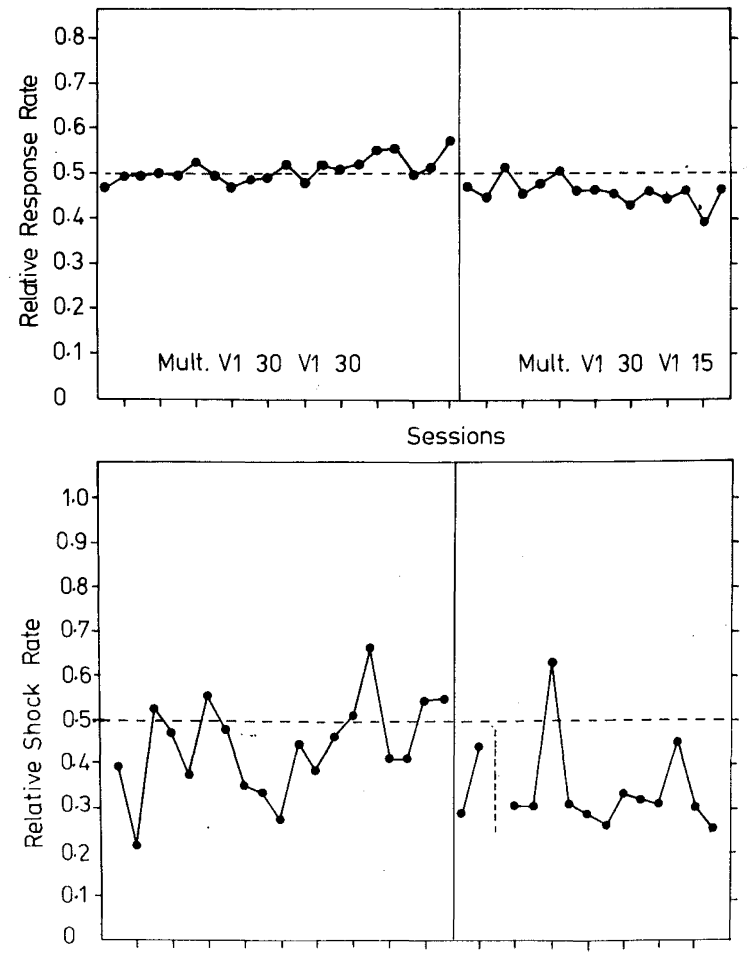
SUBJECT: R2 & F3

SHOCK FREQUENCY REDUCTION, AVERAGED PER SESSION.

S1 COMPONENT MARKED BY SQUARES, S2 COMPONENT MARKED BY TRIANGLES.

R1


Responses per min
14
12
10
8
6
4
2
Single V1 30
Mult. V1 30 V1 30
Mult, V1 30 V1 15
2 4 6 8 10
2 4 6 8 10 12 14 16 18 20
2 4 6 8 10 12 14
Sessions


Relative Response Rate
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
Mult. V1 30 V1 30
Mult. V1 30 V1 15
Sessions
Relative Shock Rate
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0

EXP. 2

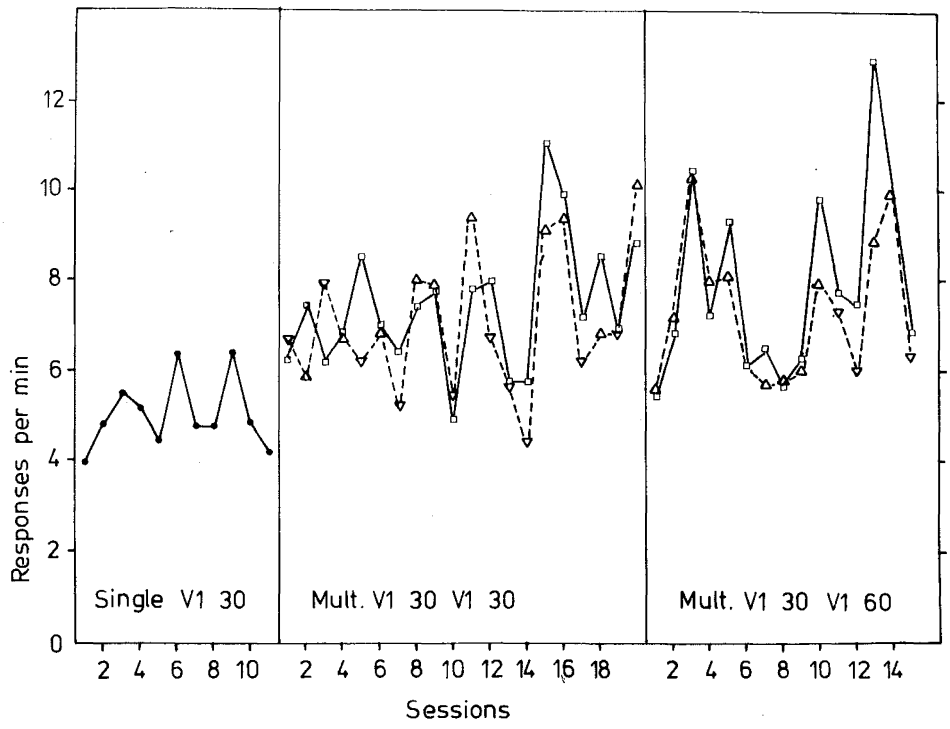
FIG. 2

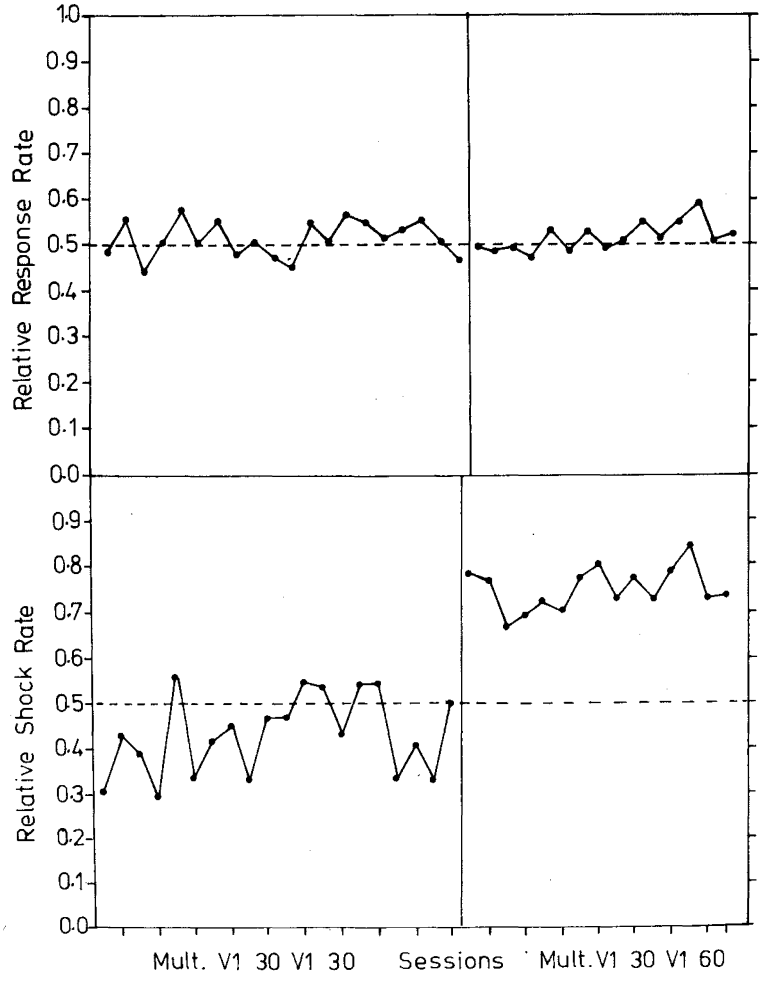
SUBJECT: R2

GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

R2


Responses per min
0
2
4
6
8
10
12
Single V1 30
Mult. V1 30 V1 30
Mult. V1 30 V1 60
2 4 6 8 10
2 4 6 8 10 12 14 16 18
2 4 6 8 10 12 14
Sessions


Relative Response Rate
Relative Shock Rate
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Mult. V1 30 V1 30
Sessions
Mult.V1 30 V1 60

EXP. 2

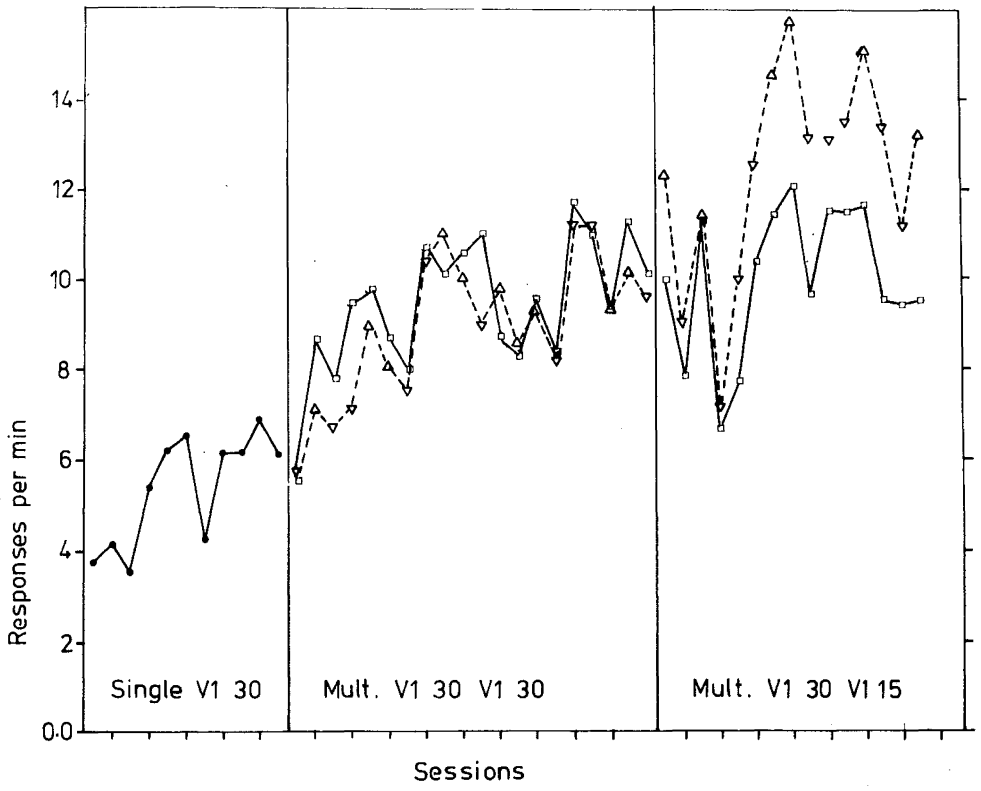
FIG. 3

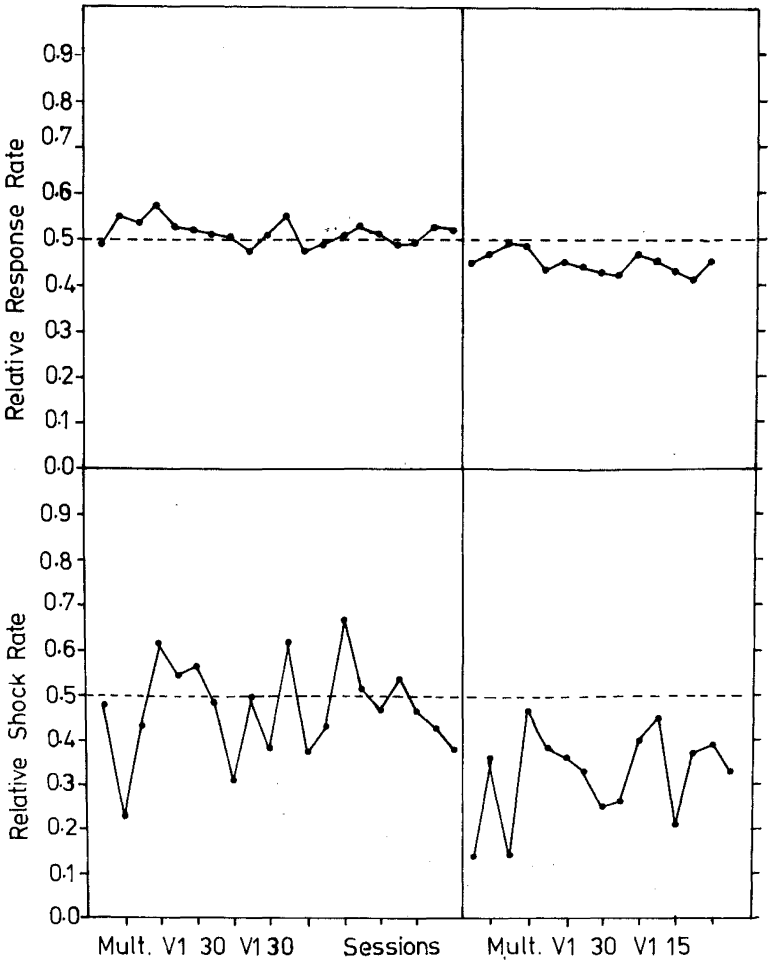
SUBJECT: R3

GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

R3


Responses per min
0.0
2
4
6
8
10
12
14
Single V1 30
Mult. V1 30 V1 30
Mult. V1 30 V1 15
Sessions


Relative Response Rate
Relative Shock Rate
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Mult. V1 30 V1 30
Sessions
Mult. V1 30 V1 15

EXP. 2

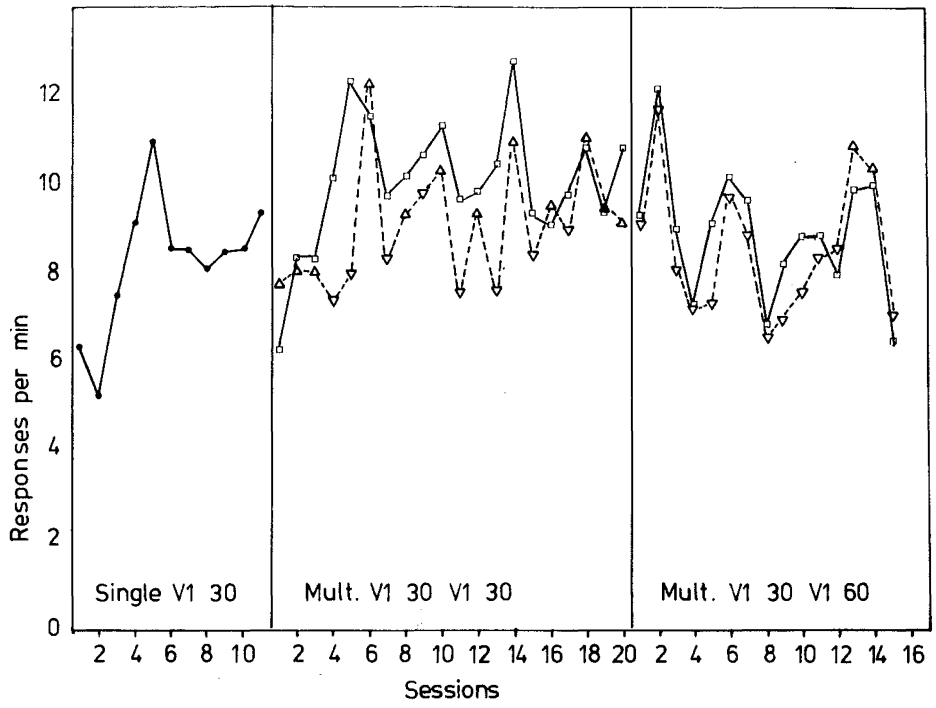
FIG. 4

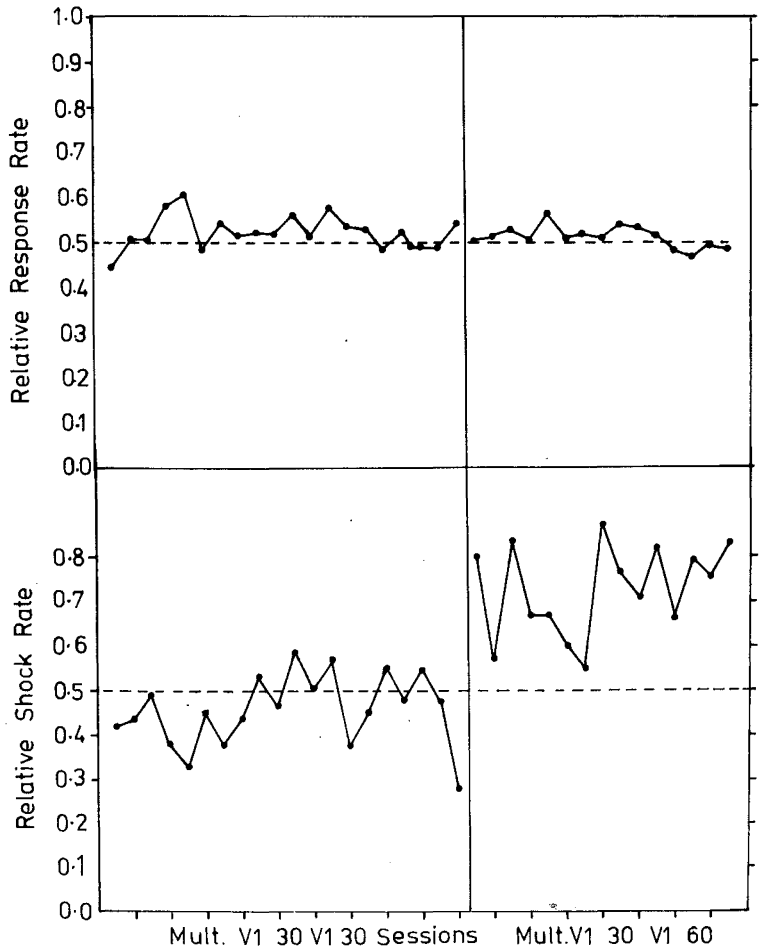
SUBJECT: R4

GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

R4


Responses per min
0
2
4
6
8
10
12
Single V1 30
Mult. V1 30 V1 30
Mult. V1 30 V1 60
2 4 6 8 10
2 4 6 8 10 12 14 16 18 20
2 4 6 8 10 12 14 16
Sessions


Relative Response Rate
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
Relative Shock Rate
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
Mult. V1 30 V1 30 Sessions
Mult.V1 30 V1 60

EXP. 2

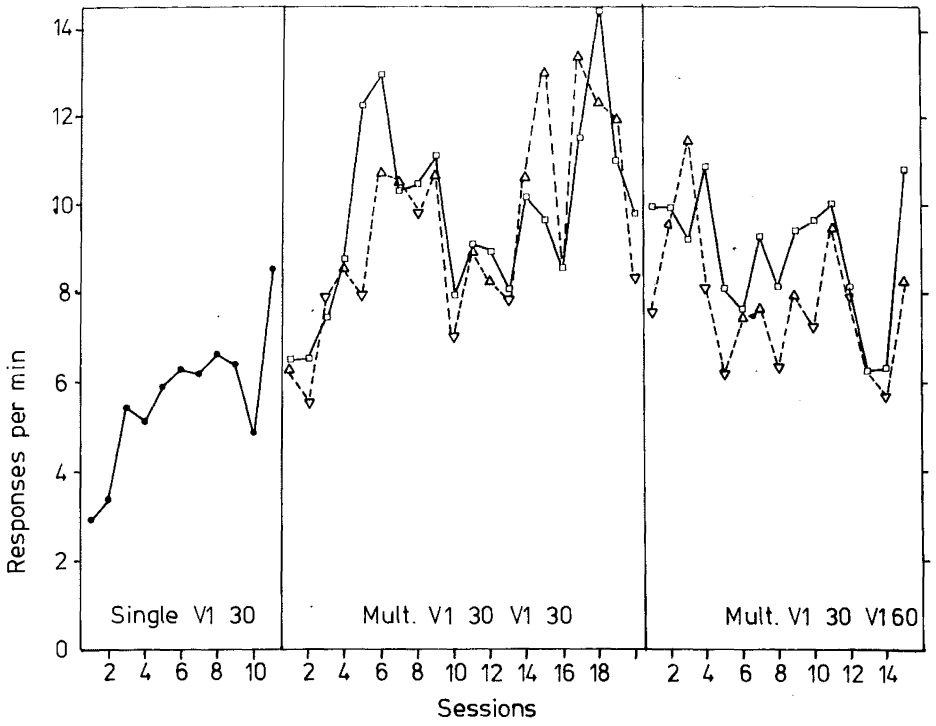
FIG. 5

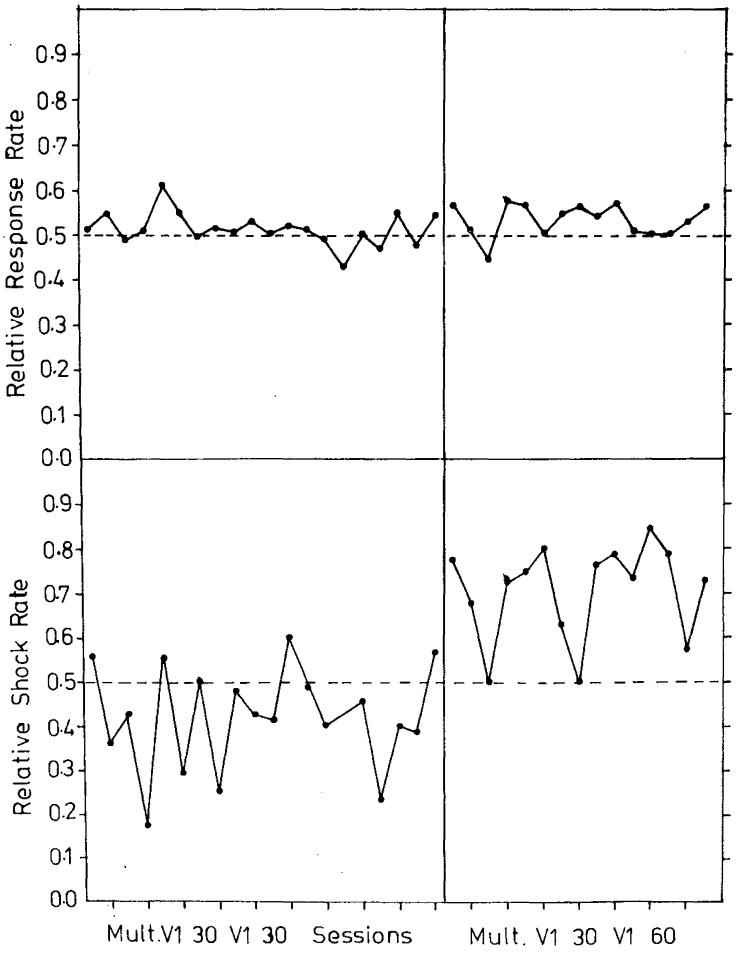
SUBJECT: R5

GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

R5


Responses per min
Single V1 30
Mult. V1 30 V1 30
Mult. V1 30 V160
Sessions


Relative Response Rate
Relative Shock Rate
Mult.V1 30 V1 30
Sessions
Mult. V1 30 V1 60

EXP. 2

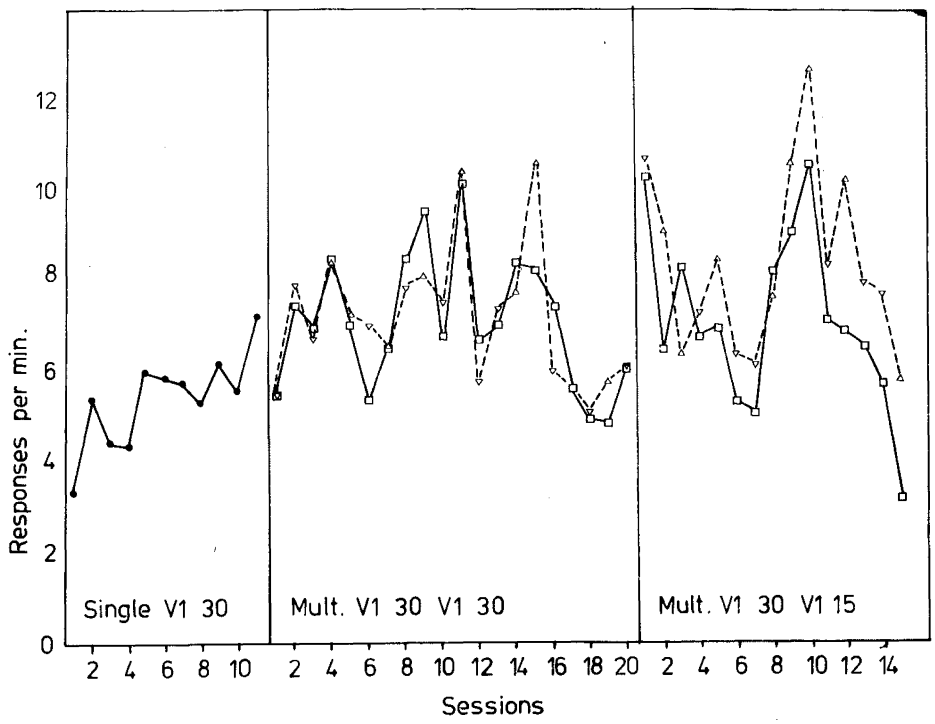
FIG. 6

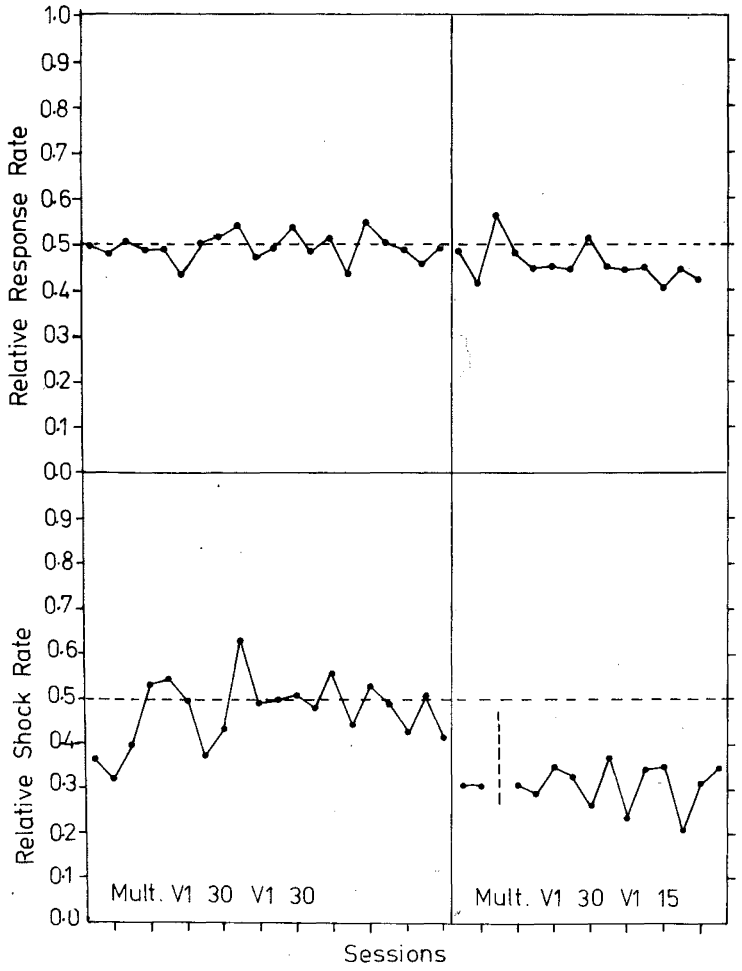
SUBJECT: R6

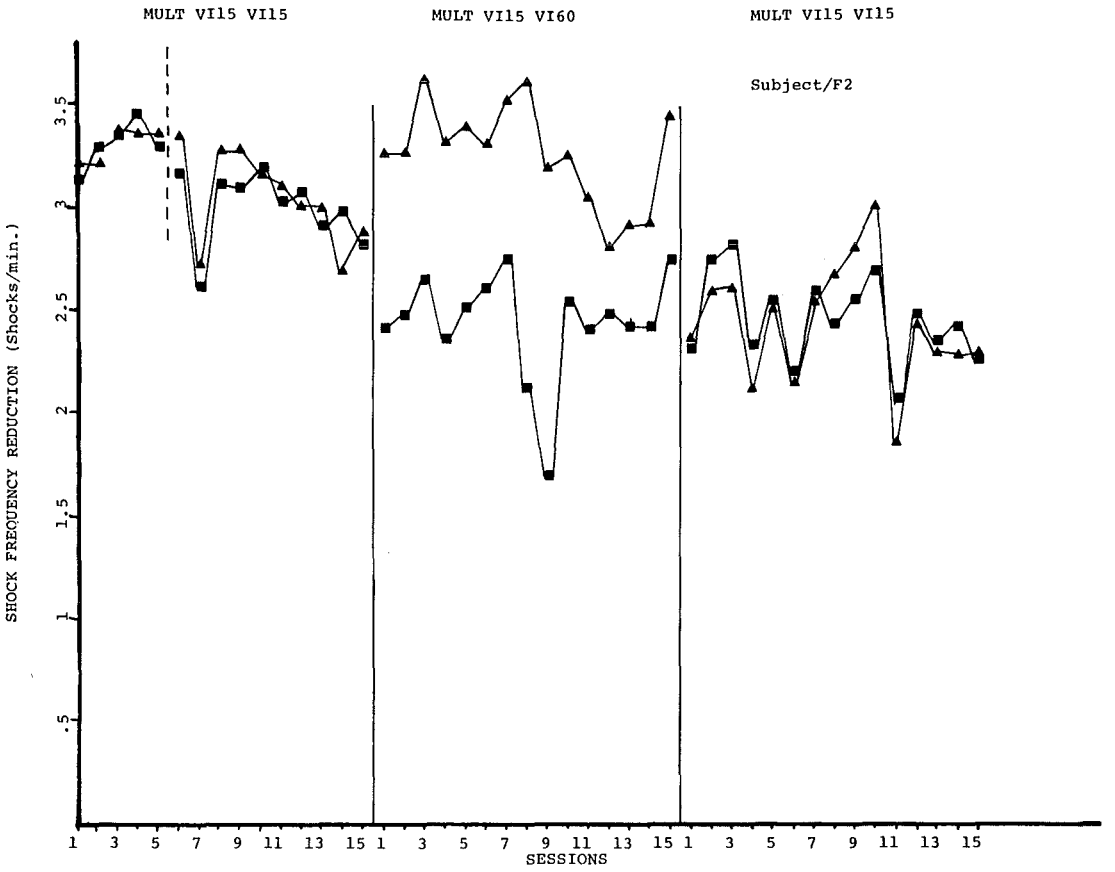
GRAPH OF AVERAGE RESPONSE RATE PER SESSION IN MULTIPLE SCHEDULES. S1 IS MARKED BY SQUARES, S2 BY TRIANGLES.

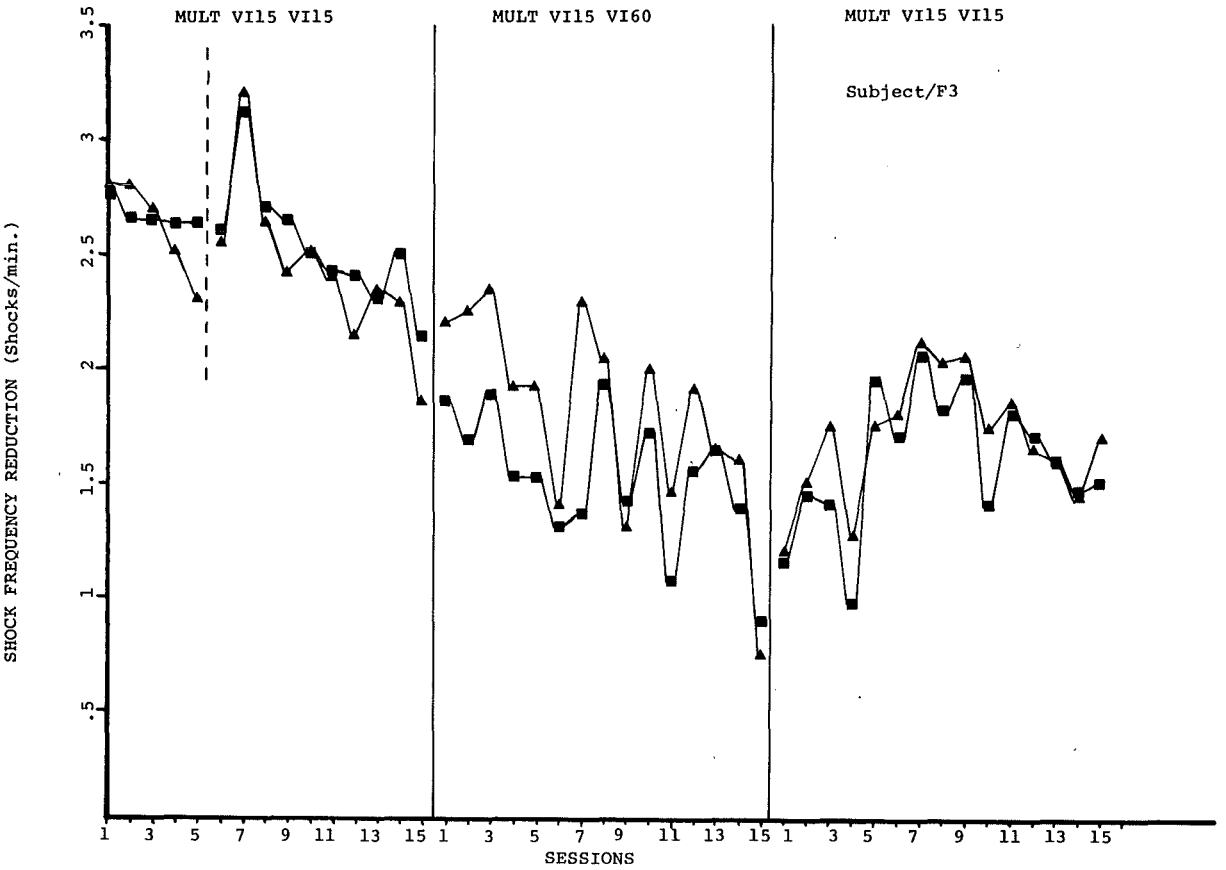
RELATIVE SHOCK, AND RELATIVE RESPONSE RATES FOR THE MULTIPLE SCHEDULES.

R6


Responses per min.
0
2
4
6
8
10
12
Single V1 30
Mult. V1 30 V1 30
Mult. V1 30 V1 15
2 4 6 8 10
2 4 6 8 10 12 14 16 18 20
2 4 6 8 10 12 14
Sessions


Relative Response Rate
Relative Shock Rate
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Mult. V1 30 V1 30
Mult. V1 30 V1 15
Sessions


MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F2
SHOCK FREQUENCY REDUCTION (Shocks/min.)
.5
1
1.5
2
2.5
3
3.5
1 3 5 7 9 11 13 15 1 3 5 7 9 11 13 15 1 3 5 7 9 11 13 15
SESSIONS


MULT VI15 VI15
MULT VI15 VI60
MULT VI15 VI15
Subject/F3
SHOCK FREQUENCY REDUCTION (Shocks/min.)
.5
1
1.5
2
2.5
3
3.5
1 3 5 7 9 11 13 15 1 3 5 7 9 11 13 15 1 3 5 7 9 11 13 15
SESSIONS

5.1 RESULTS AND DISCUSSION

Acquisition and Single VI30 Training

All subjects acquired the response readily. The average time taken to acquire the avoidance response was approximately the same as for the subjects of experiment 1, namely about 0-10 minutes. One subject did experience some difficulty, due to experimenter error. The similarity in acquisition time for the two responses is not supported by the evidence available on the subject. (Cf. D'Amato and Schiff, 1964; Bolles, 1970, 1972.) The usual finding is that the so-called 'species-specific defence reactions' (Bolles, 1970) or 'prepared' responses, (Seligman and Hager, 1972) such as jumping, running, freezing, are easily acquired, while treadle presses, bar presses, chain pulls, head pokes, etc, are difficult to learn. In the present situation, however, Bolles would argue that the similarity would in fact be expected, since the animal does not escape the setting of the aversive stimulation in a two-way shuttle box, unlike the one-way avoidance response. The crucial point, according to Bolles, is that the animal must escape from the environment in which the aversive stimulation occurs. Unfortunately, as far back as 1935 (Hunter, 1935) it was shown that running could be rapidly acquired even when it meant not escaping from the setting in which the aversive stimulation occurred. The operant rate of running is high; the operant rate of bar-pressing low; in the initial acquisition, it is doubtful if the appearance of either represents any more than the operant rate of the response. Nor can acquisition be taken as the

touchstone by which we make a comparison between response forms. In this case, bar pressing is as easily acquired, and much more efficient as an avoidance response than the two-way shuttle response. Since the present experiment does not bear directly on the problem, we shall leave the topic.

Phase 3: Mult VI30VI30

During this phase all subjects increased their rate of responding initially, and then stabilised. It was expected that day-to-day variation would be minimal, as was the case with de Villiers' results, but the data in this phase was characterized by high daily variation. (See Figures 1-6) . The overall rates of responding were lower than those of de Villiers (1972), responding in this experiment reaching a maximum of about 14 responses per minute on the VI30 schedule, compared with 15-28 responses per minute found by de Villiers. However, the contrast effect found by de Villiers was about 2-4 responses per minute higher than baseline rates of responding. If the contrast effect was of this magnitude, then it should still show up against the daily variation that was experienced. After attempting to use a 5 percent maximum variance over 3 consecutive days criteria for stability, this was rejected as being too rigid a criteria. After 20 days, the animals were split into two groups, each on a different schedule. (Either Mult VI30VI15 for R1, R3 and R6; or Mult VI30VI60, for R2, R4 and R5.)

Phase 4: Mult VI30VI15, or Mult VI30VI60

De Villiers (1972) found that a change to a higher density of shock lead to an initial positive contrast effect,

followed by negative contrast, with response rates stabilizing at 2 to 4 responses per minute lower than in the Mult VI30VI30 schedule. In the de Villiers experiment, the effect was observed after 3-7 sessions. In the present experiment, none of the data from R1, R3 or R6 support such a finding, even after 15 sessions. It is conceivable that there may be a small effect with R6 (see Figure 6), but if there is a negative contrast effect, it is a long time appearing, and it cannot really be disentangled from the daily fluctuations.

Probably the most interesting data available from these subjects is the relative response rate (Figures 1, 3 and 6) The response rate is found to be almost the same in both components, (i.e., a relative rate of responding of 0.5) on both multiple schedules. This is against all expectations. With a greater shock density in the S2 component, it is to be expected that the relative response rate would show a shift to higher responding in the VI15 component. But relative response rates remain at 0.5. This finding seriously questions any inferences that we might have made from the data available. One possible explanation of why this should happen is that the animals did not discriminate the two schedules on the basis of the cues presented, and so were effectively responding on a mixed schedule, and paced their responding to the average rate of shock, which would include shock densities in both the VI30 and VI15 components. A test for stimulus control would have been most helpful here.

Subjects R2, R4 and R5 exhibited much the same performance as the previous 3 subjects. While de Villiers (1972) found marked behavioral contrast, in the present experiment there was no evident trend in the response rates. If

anything, subjects R4 and R5 may have shown a very small negative induction effect similar to that found in experiment 1 under similar reinforcement conditions.

As was the case with the other group of rats, R3, R4 and R5 did not alter their relative rates of responding when the schedule was changed. (See Figures 2, 4 and 5.) The previous limiting statements for the other animals apply in this case also.

While granting that a functional analysis of the rat's behavior may have shown which variables gave rise to these apparently anomalous findings, lack of time prevented this being done. A test for stimulus control is the first requirement in such a situation, following which a change of stimulus, and stimulus location might have been instructive. De Villiers (1972) for example was using a buzzer, which appears to be equivalent to the tone used in these two experiments, yet he reported positive contrast.

6.1 GENERAL DISCUSSION

As has been pointed out in the discussion of both experiments reported above, there are a number of features, such as acquisition data unsupported by other researchers, long-term decrements in experiment 1, and high variability in experiment 2, which may appear to make any conclusions presented here tenuous, and uncertain.

None the less, it can be argued that if the present data are taken in the context of previous research in multiple avoidance schedules, some statements can be made concerning the types of interactions to be expected on such schedules.

In one of the two papers reporting contrast, the reported effects may in fact not be present. In the Wertheim paper (Wertheim, 1965) there appears to be, despite strange forms of analysis and presentation, a contrast effect which has a magnitude of approximately 20-50 percent above baseline rates of responding. (See Wertheim, 1965, p273, Figure 4.) This was found when the rates of scheduled shock were reduced in the S2 component. De Villiers (1972, experiment 1) claimed to have found a positive contrast effect in the same type of situation, namely where the rate of scheduled shocks had been reduced from VI15 to VI60 in the S2 component. However it may well be argued that there was in fact no effect at all. If we look at his data (de Villiers, 1972, Figure 1) we observe, in each case, an increase in responding from the Mult RI15RI15 schedule to the Mult RI15RI60. However, when going from a single RI15 to a Mult RI15RI15, there is a drop in response rate as

Herrnstein predicted there would be (Herrnstein, 1970, p265). Premack (1969) has shown for positive reinforcement that when a schedule is changed from singe VI30 (for example) to a Mult VI30Ext, the contrast so produced is the same as the contrast produced by going from a Mult VI30VI30 to the Mult VI30Ext schedule. If it is assumed that the same applied here, and we make our comparison between the single RI15 schedules and the Mult RI15RI60 schedule, then a different picture emerges. There may be a very brief (1-2 sessions) positive contrast, which then settles back to the same response rate as prevails in the first and second RI15 schedules. This would be a transient behavioral contrast effect. Most importantly, there is no evidence whatsoever that negative contrast occurred after the return to baseline conditions.

In attempting to make comparisons in this experiment, one is severely hampered by the lack of baseline data. Of the total of 38 baseline sessions, only 22 sessions at the most are reported. Why this should be so is not clear. Considering the very tenuous nature of the reported contrast, any small variation from the data presented, such as a few high data points in the Mult RI15RI15 phase would make a great deal of difference to the analysis of the alleged effect.

Thus, if we except these arguements, there has been only one demonstration of positive behavioral contrast, namely Wertheim, 1965. De Villiers has demonstrated negative contrast, when the opposite conditions to Wertheim's are used, i.e., when the shock rate in the S2 component is

increased. In the same scheduled conditions as Wertheim, Appel (1960) found negative induction, a finding that Keller's (1974) paper suggests should occur whenever the elicited (autoshaped) responses do not occur on the recorded-response manipulandum. The present study supports this conclusion, in that using a different response, with similar decline in shock frequency in the S2 component, negative induction was found. Whether or not the finding of negative induction is due to rates of scheduled shock, or to the non-localized component signal is a matter for research. Appel (1960), de Villiers (1972), and the present research have all employed non-localized stimuli to signal the two components of the multiple schedule. Wertheim, however, used a signal light immediately above the lever. From the discussion of additivity theory, it is apparent that the role of signal location is an important avenue for future research. (Cf. Schwartz, 1975.) The failure of experiment 2 of this study to yield reliable data should be viewed as a consequence of experimental noise, and not as a result of any schedule interaction. This is clearly shown by the failure of the animals to change their relative rates of responding in the experimental phase. It may well be that the use of multiple baselines, and more divergent schedules, would give more significant results. For example, instead of changing from VI30 to VI15 or VI60, it may be better to start with Mult VI15VI15, and change to Mult VI15VI60, and also from Mult VI60VI60 to Mult VI60VI15.

The response modality is also an important variable. If, with later research, autoshaping with negative reinforce-

ment is demonstrated, implying that it is conceivable that elicited responses may contribute to contrast in rats, then it will also be necessary to show if autoshaping occurs for different responses, such as the two-way shuttle, that contrast also occurs. If it does not, then this will seriously weaken an additivity theory of contrast.

Not only response differences will have to be considered; whether or not contrast occurs equally well with either free-operant, or variable interval avoidance is also a matter for research. The temporal patterns associated with free-operant avoidance are not present to the same degree in variable interval avoidance. Preferably the variable interval avoidance would be used. The regularity of the data generated by variable interval schedules (excluding our experiment 2) gives an excellent baseline on which to make comparisons between responses rates in various components.

One of the most serious objections that might be made against the findings presented here is the objection that what is occuring is a failure by the discriminative stimulus for the components to achieve stimulus control over responding. This would make the schedule a mixed schedule, and might well explain the rather odd results obtained in experiment 2. Appel (1960) has calculated discriminability indices for his rats, which suggest that the rats did in fact discriminate. But this may also be explained by suggesting that the rats are responding to received shock, and not to the overall detected probability of shock, as suggested by de Villiers (1972, 1974). Anecdotely, when the rats in experiment 1 were observed, they did appear to respond only just after the shock had

been delivered. To overcome these objections, firm data is needed, in the context of an experiment showing multiple schedule interations, that stimulus control of responding was exerted by the discriminative stimulus used to signal the components of the multiple schedule. This might take the form of a generalization gradient. For example, two stimuli, varying along some orthoganal dimension, such as frequency, might be used as signals. Stimulus control probes might be dropped into the experimental sessions and the rates of responding to various stimuli along the dimension used could be taken. This should presumably show that rats responded faster to stimuli closer to the stimuli which signals the higher rates of scheduled shock, and slower to the stimuli signalling lower rates of scheduled shock.

In the opinion of the writer, the analysis of multiple schedule interactions using negative reinforcement might well benefit from some form of demonstration that the signals used as discriminative stimuli for the components of the schedule do in fact exert stimulus control over the on-going behavior.

7.1 CONCLUSIONS

The research described was originally designed to show that behavioral contrast can be found in subjects other than pigeons, and on schedules other than those employing positive reinforcement. The first point has in fact been taken up by others, (cf. Gutman, Sutterer and Brush, 1975; Beninger and Kendall, 1975) reported after the commencement of the present research, but the second question remains in need of clarification.

When, however, we consider the research which has been carried out using negative reinforcement, including that presented here, there are some conclusions that appear reasonable. If the lever is near the component signal, and if the signal is localized, then contrast will occur if the S2 component is a schedule which uses a reduced rate of scheduled shock. If, however, the stimulus which signals the components is not localized, then no effect, or negative induction will most probably result. (Appel, 1960, present experiments 1 and 2, and our interpretation of de Villiers, 1972, experiment 1.) When a higher density of scheduled shock is programmed in the S2 component, negative contrast may be expected. (de Villiers, 1972, exp.2.) While it was originally thought that some comment could be made about the role of the response modality in behavioral contrast with negative reinforcement using experiment 1, the experiment confounded stimulus location and response modality, since we cannot say whether or not we would have got contrast if the signal had been a visual one.

Future directions for research are numerous.

Signal location, (Schwartz, 1975) duration, (Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger and Ricci, 1975) and type, (Stiers and Silberberg, 1974; Miller, 1973) are all important variables in positive behavioral contrast with positive reinforcement, and the role of the stimulus in negative reinforcement should, on an additivity theory of contrast, be most important in controlling the outcome of experiments in this field.

In those situations in which positive behavioral contrast can be shown to occur, autoshaping of the response involved should be possible. This opens up the importance of extending autoshaping experiments to negative reinforcement situations. The work of Rachlin, 1969, needs extension urgently. In each situation where autoshaping may occur, there must be, theoretically, a perfect relationship between the ability to autoshape some response, say the nose-poke, and the ability to show the occurrence of positive behavioral contrast with that response. If a response can be autoshaped, but positive behavioral contrast cannot be obtained, then this will seriously weaken the additivity theory, and its extensions to other species.

As we have argued, demonstrations of stimulus control in the context of positive behavioral contrast, and negative induction, are needed to reply to the possible objection that what is happening is that the rats are not discriminating, and hence are responding on mixed schedules of reinforcement, not multiple schedules.

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